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ORIGINAL PAPER

Characteristics of life-form and growth-form of plant species in an alpine ecosystem of North-West Himalaya

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Abstract: The present study was conducted in the alpine pastures of Tungnath (30° 14' N and 79° 13' E) to observe life-form and growth-form patterns of alpine plant species under grazed and ungrazed conditions and to work out the plant life form spectrum. Species were categorized as plant habit, height and length of growth-cycle and life-form classes according to Raunkiaer's system. The results show that in total of 68 species at grazed site, hemicryptophytes (He) accounted for 50.00% species, followed by cryptophytes (26.47%), chamaephytes (16.18%), phanerophytes (4.41%) and therophytes (2.94%). At the ungrazed site in 65 plant species, hemicryptophytes (He) accounted for 49.23% species, cryptophytes (26.15%), chamaephytes (15.38%), phanerophytes (6.15%) and therophytes (3.08 % species). In general, hemicrptophyte are dominant in both sites i.e. graged and ungrazed. Growth form categories were classified as forbs, shrubs, grasses and sedges and undershrubs, according to plant habit and height. On the basis of length of the growth cycle, species were categorized as plant species of short growth cycle, intermediate growth cycle and long growth cycle. The short forbs of plant habit and height, had the highest emergence, and grasses and sedges had the lowest emergence in representative species. Percentage of species with long growth cycle was highest in both sites.

Keywords: Alpine; biological spectrum; growth form; Himalaya; life form

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Introduction

The distribution and productivity of plant species in alpine regions are clearly affected by variation of climate and topography. This variation often occurs at spatial scales of one to a few meters and can be quite extreme factor for plants in adverse climatic conditions. The plants became generally dwarfed, stunted, wooly or spiny, and then a mosaic patch in different plant regions was developed.

In Himalaya, alpines are the landscapes between treeline and snowline, and are known as high altitude "bugyals", where the vegetation consists of short–stemmed perennial herbaceous plants, semi–prostrate shrubs, ferns, lichens and mosses. The alpine meadows have been grazed by the migratory animals of the inhabitants in adjacent lower valleys and gujjars during snow-free period (May-September). In alpines, sheep flock usually travels the same route, where the areas are grazed by the first arrivals and also by the local domestic village animals. Each year bare sites are also created (0.5–1.0 ha) within the alpine meadows as a result of night camping of animal herds, particularly of sheep's and goats (Singh 1991), which is affecting the ecology systems of the Garhwal Himalayan alpine meadows (Ram et al. 1994).

Vegetations in the alpine zone exhibit a characteristic adaptation to the environment and therefore have distinct growth forms. The plants possess an early growth_initiation in an early period ranging from several days to a few months to develop different plant forms (Nautiyal et al. 2001). In addition, species has a preference for growing under various degrees of biotic stresses. The present study emphasized all these parameters to observe life-form and growth-form patterns of alpine plant species under grazed and ungrazed conditions.

Materials and methods

Field inventory

The present study was carried out in the alpine pastures of Tungnath (30°14' N and 79°13' E), between altitudes of 3 200 m and 3 800 m above mean sea level. The present alpine region is at two popular summits, namely, Rawanshila (3 400 m) and Chandrashila (3 800 m). The timberline in this area reaches upto an elevation of 3200 m. Important species at timber line are *Quercus semecarpifolia*, *Abies pindraw* and *Betula utilis* (Sundriyal et al. 1988). The rocks around Tungnath are mainly mylonitized gneisses, augengneisses, schist and granite. The main rock components are crystalline and metamorphic, with sedimentary deposits. The rocks are sandwiched between Munsiari Thrust in the south and vaikrita thrust in the north (Valdiya 1980). The flat topographic features are probably the result of the Quaternary glaciation (Pangtey et al. 1994). The soil cover gradually becomes thinner with increasing altitudes. The south faces of sites are mostly with large rock spurs and crevices. The soil is loam or sandy loam, light grey to brown in color at lower altitudes. Water holding capacity of the surface soil is reported as meager and pH ranges from 4.9–5.6 (Semwal 1981).

Climatological observations

Like other alpine and arctic zones of the globe, the climate of this alpine zone is cold, with intense irradiance and low partial gas pressure. Heavy frost, blizzards and hailstorms prevail throughout the year except for a few months of summer. In the region, snowmelt occurs during April-May, resulting in abundance of soil moisture. Even in May, before the rainy season, the cloud formation is a common feature. During day time, heat is lost due to the cold winds and nights are colder. Average maximum temperature was recorded in August (21.23 °C) and minimum in October (6.06 °C). Maximum rainfall was recorded in August (1550.31 mm) and minimum in May (139.81 mm). Maximum humidity was recorded in August (70.97 %) and lowest in October (46.65 %).

Site description

For the observations, fenced enclosure of about 5-ha area of Alpine Field Station (Tungnath) was considered as ungrazed site. Similarly, an adjoining area outside (area open for grazing) the alpine field station was marked as grazed site that is grazed by large herds of cattle of local inhabitants from down-valley and gujjars (nomadic people) every year (Rawat et al. 2010). The study was carried out from May to October during the growth period of plants in 2007 for intensive plant collection and observation.

Various growth forms of plants were classified according to plant habit and height as follows: (1) Shrubs and undershrubs (Hedberg 1973; Körner 1999); (2) Tall forbs (> 30 cm height) (Pandey et al. 1999); (3) Short forbs (< 30 cm height); (4) Grasses and sedges. Similarly, based on the length of growth cycles, species were categorized as follows: (1) plant species of short growth cycle within two months; (2) plant species of intermediate growth cycle with a life span of 2–4 months; (3) plant species of long growth cycle with life span in more than 4 months (Pandey et al. 1999; Nautiyal et al. 2001). Life-forms of plants were studied in both the alpine localities (grazed and ungrazed). The form, habit, height and the location of perennating buds of alpine plant species were observed. The plant species further were placed into various life-form classes according to Raunkiaer's system (Raunkiaer 1934) *viz*., phanerophytes (Ph), chamaephytes (Ch), hemicrptophytes or hemigeophytes (He), cryptophytes or geophytes (Cr) and therophytes (Th).

Results

A total of 68 plant species from grazed site and 65 from ungrazed site were recorded (Table 1). Both the sites were dominated by tussock and stoloniferous graminoids (plant species belonging to the family-Poaceae) *viz*., *Agrostis munroana*, *Danthonia cachemyriana*, *Kobresia duthiei*, *Poa annua*, etc.

Characteristics of plant growth form according to plant height and habit

Monthly observations of total species (%) at grazed and ungrazed sites are shown in Table 2. The data revealed that percentage of shrubs and undershrubs was maximum in July (8.33 %) and minimum in October (5.26 %) at grazed site. On the other hand at ungrazed site, percentage of shrubs and undershrubs was maximum in September (5.71 %), whereas minimum in August (2.00 %). In case of tall forbs (>30 cm), maximum percentage was recorded in September (28.57 %) and minimum in May (18.52 %) at grazed site. At ungrazed site, maximum percentage of tall forbs was in October (31.82 %) and minimum in May (16.67 %). Short forbs (< 30 cm) had maximum percentage in May (44.44 %) and minimum in October (21.05 %) at grazed site. At ungrazed site, maximum percentage of short forbs was in July (50.00%) and minimum in September (31.43 %). Spreading and cushion forming forbs had maximum percentage in October (42.11 %) and minimum in September (25.00 %) at grazed site. At ungrazed site, forbs had maximum percentage of in June (28.57 %) and minimum in August (20.00 %). At grazed site, grasses and sedges had maximum percentage in May (11.11 %) and minimum in July (4.17 %). In case of ungrazed site, maximum percentage of grasses and sedges was in May (12.50 %) and minimum in June and September (5.71 %).

Characteristics of plant growth form according to length of growth cycle

In present observations, plant species with long growth-cycle had maximum percentage in September (85.71 %), followed by intermediate growth cycle plant species (33.33 %) in May and then short growth cycle plant species (2.08 %) in July at grazed site.

At the ungrazed site, similar trend was observed *i.e*. plant species with long growth cycle had maximum percentage in September (74.29 %), followed by intermediate growth cycle plant species (36.00 %) in August and then short growth cycle plant species (1.72 %) in July (Table 3).

Table 1. Existence of species at grazed and ungrazed sites (+ denotes presence and - denotes absence)

Species	Grazed	Ungrazed	Species	Grazed	Ungrazed
Agrostis munroana Ait. Et Hemsl.	-	+	*Pimpinella diversifolia* DC.	-	+
Anagallis arvensis L.	+	-	*Plantago depressa* Willd.	+	+
Anaphalis contorta (D.Don.) Hook f.	+	-	*Plantago major* non L.	+	+
Anaphalis cuneifolia Hook f.	+	+	*Poa annua* L.	+	+
Anaphalis margaritacea (L.) Benth.	+	-	*Polygonatum geminiflorum* Decne.	+	+
Anemone obtusiloba D. Don.	-	+	*Polygonum affine* D. Don.	+	-
Anemone rivularis Buch. – Ham. Ex DC.	-	+	*Polygonum alpinum* All.	+	+
Arenaria ciliolata Edgew.	+	+	*Polygonum amplexicaule* D. Don.	+	+
Astragalus himalayanus Klotz.	-	+	*Polygonum aviculare* L.	+	+
Caltha palustris L.	+	-	*Polygonum emodi* Meissn.	+	+
Carex nubigena D. Don	+	+	*Polygonum macrophyllum* D. Don.	+	+
Cassiope fastigiata (Wall)D. Don	+	-	*Polygonum rumicifolium* Royle ex Bab.	+	+
Clematis barbellata Edgew.	+	-	*Potentilla atrosanguinea* Lodd.	+	+
Corydalis cashemiriana Royle	+	+	*Potentilla cuneata* Wall. ex Lehm.	+	+
Corydalis longipes DC.	-	+	*Potentilla fulgens* Wall. ex Hook.	+	+
Cotoneaster microphyllus Wall. ex Lindl.	-	+	*Potentilla microphylla* D. Don.	+	+
Cypripedium elegans Rechb. F.	-	+	*Primula denticulata* Sm.	+	+
Danthonia cachemyriana Jaub. & Spach.	+	+	*Ranunculus hirtellus* Royle ex D.Don	+	+
Epilobium angustifolium L.	-	+	*Rhododendron campanulatum* D. Don.	+	+
Erigeron floribundus (H.B.K.) Sch.-Bip.	+	-	*Rosa brunonii* Lindl.	+	-
Euphorbia stracheyi Boiss.	+	+	*Roscoea purpurea* J. C. Sm.	+	-
Fragaria nubicola Lindl.ex Lacaita	+	+	*Rumex nepalensis* Spreng.	+	+
Galium aparine L.	+	-	*Salix lindleyana* Wall. ex Anders.	+	+
Gaultheria trichophylla Royle	+	+	*Salvia hianes* Royle ex Benth.	+	-
Gentiana argentea (D. Don.) Cl.	+	+	*Saussurea taraxifolia* Wall. ex DC.	+	+
Geranium wallichianum D. Don ex. Sw.	+	+	*Saxifraga diversifolia* Wall. Ex Sering.	+	-
Geum elatum Hook. f.	+	+	*Sedum imbricatum* (Edgew). Walp.	+	-
Hackelia uncinata (Royle ex Benth.) C.E.C. Fischer	+	-	*Selinum candollii* DC.	+	+
Hypericum hookerianum Wt. & Arn.	-	+	*Selinum vaginatum* (Edgew.) Cl.	+	+
Iris kemaonensis D. Don. ex Royle.	+	-	*Senecio chrysanthemoides* DC.	+	-
Juncus bracteatus Buchen	-	+	*Sibbaldia micropetala* (D. Don.) Hand.- Maz.	-	+
Jurinea macrocephala (Royle) Cl.	+	+	*Sibbaldia parviflora* Willd.	-	+
Kobresia duthiei Cl.	-	+	*Sorbus aucuparia* L.	-	+
Liuglaria amplexicaulis DC.	+	-	*Sorbus foliolosa* (Wall.) Spach	-	+
Lloydia serotina (L.) Reich	-	+	*Stachys sericea* Wall. ex Benth.	+	+
Malaxis muscifera (Lindl.) Kuntz.	-	+	*Swertia cuneata* D. Don.	-	+
Morina longifolia Wall. ex. DC.	+	+	*Swertia speciosa* D. Don.	+	+
Origanum vulgare L.	-	+	*Tanacetum longifolium* Wall. ex DC.	+	+
Onosma emodi Wall.	+	-	*Taraxacum officinale* (Weber) Wiggers	+	+
Orchis chusua D. Don	+	-	*Teucrium quandrifarium* Buch.-Ham. ex D. Don	+	-
Oxyria digyna (L.) Hill	+	-	*Trachydium roylei* Lindl.	+	+
Parnassia nubicola Wall. ex Royle	+	+	*Viburnum cotinifolium* D.Don	+	-
Pedicularis gracilis Wall. ex Benth.	+	+	*Viola biflora* L.	+	+
Phlomis bracteosa Royle ex Benth.	-	+	*Osmunda* species (Fern)	+	+
Picrorhiza kurrooa Royle ex Benth.	+	-			

Table 2. Monthly variation of different growth forms of plants at grazed and ungrazed sites (%)

Growth forms	May		June		July		Aug.		Sept.		Oct.	
	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Shrubs and under shrubs	-	-	5.88	2.86	8.33	3.45	7.89	2	7.14	5.71	5.26	-
Tall forbs (>30 cm at height)	18.52	16.67	23.53	22.86	22.92	17.24	18.42	20	28.57	31.43	21.05	31.82
Short forbs <30 cm	44.44	45.83	41.18	40	41.67	50.00	39.47	48	32.14	31.43	21.05	31.82
Spreading and cushion forming forbs	25.93	25	23.53	28.57	22.92	20.69	28.95	20	25	25.71	42.11	27.27
Grasses and sedges	11.11	12.5	5.88	5.71	4.17	8.62	5.26	10	7.14	5.71	10.53	9.09

Table 3. Monthly variation in growth initiation of plants at grazed and ungrazed sites

Growth initiation categories	May		June		July		Aug.		Sept.		Oct.	
	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Short growth cycle 2 months	7.41	8.33	2.94	5.71	2.08	1.72	2.63	2.00	0	0	0	0
Intermediate cycle 2-4 months	33.33	25.00	26.47	34.29	27.08	34.48	28.95	36.00	14.29	25.71	15.79	27.27
Long cycle more than 4 months	59.26	66.67	70.59	60.00	70.83	63.79	68.42	62.00	85.71	74.29	84.21	72.73

Characteristics of plant growth form according to morphological features

Leaf rosettes

This category was represented by 27 and 24 species, respectively at grazed and ungrazed sites. Dominant species of this category at the sites were *Anemone rivularis*, *Plantago depressa*, *Pedicularis gracilis*, *Potentilla atrosanguinea*, *Primula denticulata*, etc.

Hairy growth

This category of plants with airy growth was represented by 7 and 4 species at grazed and ungrazed site. Development of hairs on various aerial parts is a common adaptive feature to cope rigorous and extreme cold alpine environment. Representive species with hairy growth are, viz., *Onosma emodi*, *Ligularia amplexicaule* and *Origanum vulgare*.

Grass tussock community

Agrostis munroana, *Danthonia cachemyriana*, *Kobresia duthiei*, *Carex nubigena* and *Poa annua* were the common species with dense tussocks.

Prostrate growth

Alpine plant species favors prostrate growth in order to resist the excessive damage of aerial parts due to severe alpine extremities for eg. *Astragalus himalayanus*, *Geranium wallichianum*, *Potentilla fulgens*, *Ranunculus hirtellus*, etc. This category was represented by 19 species at grazed as well as at ungrazed sites.

Acaulescent habit

In this type, stems are nearly absent and flowers are born between leaf rosettes eg. *Gentiana argentia* and *Primula denticulata* and *Oxygraphis polypetala*. This category included 3 species at grazed site and 4 species at ungrazed site.

Dense cushion

Some plants of alpine region protect themselves against freezing temperature under snow by forming a dense cushion interwoven with their stems and leaves at the ground surface, such as *Cotoneaster microphyllus* and *Gaultheria trichophylla*. *Cotoneaster microphyllus* forms hard cushion. *Gaultheria trichophylla* develops soft cushions. This category included 3 species at grazed site and 4 species at ungrazed site.

Sclerophyllous growth

For controlling over water diffusion and gaseous exchange, drought-resistant species e.g. *Morina longifolia* bear sclerophyllous leaves. This category included 2 species at grazed site and 3 species at ungrazed site.

Succulent habit

Due to reduced atmospheric temperature, aridity, rapid runoff and permafrost, the moisture availability of plants is reduced considerably. The habitats are inhabited by succulents that are well adapted to these conditions i.e. Crassulaceae (*Sedum imbricatum*). This category was represented by 3 and 1 species, respectively at grazed and ungrazed site.

Life form spectrum

Observation of life form pattern reveals that in total of 68 species at grazed site, hemicryptophytes (He) accounted for 50% species, followed by cryptophytes (Cr) for 26.47%, chamaephytes (Ch) for 16.18%, phanerophytes (Ph) for 4.41% and therophytes (Th) for 2.94% species. Similarly, at the ungrazed site, hemicryptophytes (He) accounted for 49.23% species, cryptophytes (Cr) for 26.15%, chamaephytes (Ch) for 15.38%, phanerophytes (Ph) for 6.15%. and therophytes (Th) for 3.08 % species, in total of 65 species (Table 4).

Table 4. Percentage of different life forms of plants at grazed and ungrazed sites (%)

Life forms	Grazed sites	Ungrazed sites
Hemicryptophytes (He)	50.00	49.23
Cryptophytes (Cr)	26.47	26.15
Chamaephytes (Ch)	16.18	15.38
Therophytes (Th)	2.94	3.08
Phanerophytes (Ph)	4.41	6.15

Notes: There are in total of 68 species at grazed sites and 65 species ungrazed sites.

Discussion and conclusions

In plant communities, biological diversity depends on that different plant species having different physiological combinations and structural traits are able to grow and reproduce (Schwinning et al. 1998). Semwal et al. (1981) reported 176 species, while Nautiyal et al. (2001) reported 171 plant species from the alpine region of Tungnath. In the present study, we have recorded 68 species at the grazed and 65 at the ungrazed site from this region. The reduction in the total number of species in this study is probably due to varying microhabitats and different intensities of grazing. According to plant height and habit, short forbs had maximum percentage at the ungrazed site (50.00 %, July) whereas shrubs and undershrubs had minimum percentage at the ungrazed site (2.00 %, August). Similar pattern was reported by Ram et al. (1988). Most of the plant species belonged to the leaf rosette category. The plant species belonging to sclerophyllous and succulent category were also recorded. Same pattern was reported by Pandey et al. (1999) in alpine meadow of Panwalikantha in Garhwal Himalaya.

According to length of growth cycle, species with long growth cycle at grazed site indicate adaptation of plants (Körner 1999). The rise of temperature after May is in favor of growth initiation. The plant species number at vegetative growth phase was observed to be maximum in July-August. In the herbaceous community, plant species number is maximum in August (Rana 1985). All grasses and sedges had long growth cycle because their growth initiation started before 30 May and was completed before October (May et al. 1982). Some researchers showed that most of alpine plants at high latitudes complete their life cycle within two to four months (Bliss 1966; Billings et al. 1968).

On the basis of structural and functional similarities, plant species can be grouped into different classes of life-forms. It is shown usually that growth form of plants displays an obvious relationship to key environmental factors (Moradi et al. 2010). However, life form pattern did not show any noticeable differences at grazed and ungrazed sites. Hemicryptophytes and cryptophytes were dominant life-forms, which is different from normal Raunkiaer's biological spectrum. Earlier, Sundriyal (1994) and Nautiyal (1996) reported that hemicryptophytes and therophytes were dominating in Tungnath and Panwalikantha area of Himalayan region. However, Ram and Arya (1991) reported that chamaephytes and phanerophytes as dominant life-forms were in Rudranath alpine region. Rawat et al. (1987) and Gupta et al. (1983) documented that chamaephytes and hemicryptophytes as dominant life-forms for the snowline vegetation at central Himalaya. In the present study, hemicryptophytes had highest percentage of species, followed by cryptophytes, chamaephytes, phanerophytes and therophytes at both grazed and ungrazed sites. Nautiyal et al. (2001) reported that the native vegetation was disturbed due to having therophytes in an area. The lesser number of therophytes in the present study confirms that the native vegetation remained unaffected by grazing. The results further confirm that co-dominance of cryptophytes in the present area was because of a lesser effect of grazing intensity on biological spectrum of alpine region (Sundriyal 1994).

Besides these biotic influencing factors, climate changes can also influence plant changes in species composition and dominance-diversity patterns. In climatic conditions, increasing temperature is in favor of early initiation of plants, which increases the length of growing season to increase long growth cycle of plants. Körner (1999) reported that combination of rising temperatures and longer season alone is in favor of life forms of some dominant alpine plants. Also, environmental heterogeneity is an important mechanism promoting co-existence of similar species. It is widely accepted that two species that can not co-exist locally in a homogenous habitat may nonetheless co-exist stably in a network of many habitat patches. In general, plants with short growth cycle expanded initially during the onset of favourable conditions, and plants with long vegetative growth cycled subsequently exist during rest of the growth period.

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